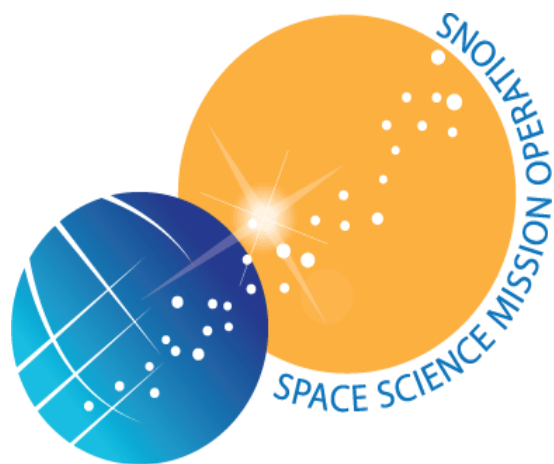


The Virtualized Multi-Mission Operations Center (vMMOC) and its Cloud Services



Presented by

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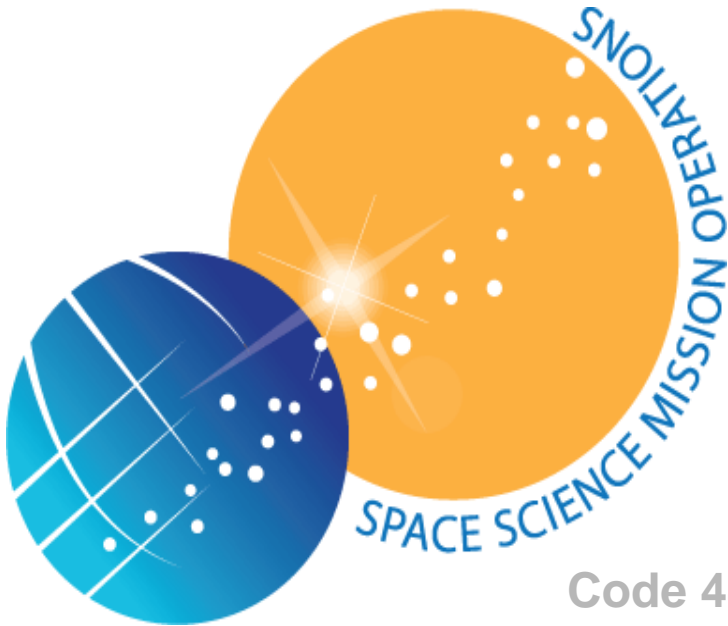
Objective of Presentation



- **What is Space Science Mission Operations (SSMO)?**
- **What is the vMMOC?**
- **Available vMMOC Services**
- **“Looking Beyond the Horizon”**



What is Space Science Mission Operations (SSMO)?



Code 444.0

Goddard
SPACE FLIGHT CENTER



What is Space Science Mission Operations (SSMO)?



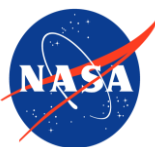
- **SSMO** provides project oversight for 19 NASA *space science* missions for which GSFC is responsible
- **SSMO** has a diverse set of missions:
 - heritage/launch date
 - orbit regime
 - spacecraft bus type
 - mission profile
 - communication networks
 - In-house and Out of House Mission Operations Centers (MOCs)



SSMO Spacecraft in Operations



| Mission | Launch Year | MOC Location | Science Type | # s/c | Orbit Regime | Catalog # |
|---|-------------|--------------|-------------------|-------|---|----------------------------|
| ACE | 1997 | GSFC | Heliophysics | 1 | L1 | N/A |
| AIM | 2007 | LASP | Heliophysics | 1 | LEO | 31304 |
| ARTEMIS* | 2007 | UC Berkeley | Heliophysics | 2 | P1, lunar orbit; P2, Lunar Lagrange Point 1 | 30581, 30582 |
| Fermi | 2008 | GSFC | Astrophysics | 1 | LEO | 33053 |
| IBEX | 2008 | Orbital | Heliophysics | 1 | HEO (T = 9 days) | 33401 |
| IRIS | 2013 | ARC | Heliophysics | 1 | LEO | |
| LRO | 2009 | GSFC | Planetary (Lunar) | 1 | Lunar Orbit | N/A |
| MAVEN | 2013 | LM - Denver | Planetary | 1 | Mars Orbit | N/A |
| MMS | 2015 | GSFC | Heliophysics | 4 | HEO | 40482, 40483, 40484, 40485 |
| OSIRIS-REx | 2016 | LM-Denver | Planetary | 1 | Heliocentric | N/A |
| Van Allen Probes (RBSP) | 2012 | APL | Heliophysics | 2 | HEO | 38752, 38753 |
| RHESSI | 2002 | UC Berkeley | Heliophysics | 1 | LEO | 27370 |
| SDO | 2010 | GSFC | Heliophysics | 1 | GEO | 36395 |
| SOHO** | 1995 | GSFC | Heliophysics | 1 | L1 | n/a |
| STEREO | 2006 | APL | Heliophysics | 2 | Heliocentric | n/a |
| Swift | 2004 | Penn State | Astrophysics | 1 | LEO | 28485 |
| THEMIS | 2007 | UC Berkeley | Heliophysics | 3 | HEO | 305880, 30584, 30585 |
| TIMED | 2001 | APL | Heliophysics | 1 | LEO | 26998 |
| WIND | 1994 | GSFC | Heliophysics | 1 | L1 | n/a |



What is the virtualized Multi-Mission Operations Center (vMMOC)?

The vMMOC's Objectives are ...

- *Rapid and efficient provisioning and orchestration of spacecraft mission operation environments.*
- *Break the barrier to mission operations and enhance accessibility*



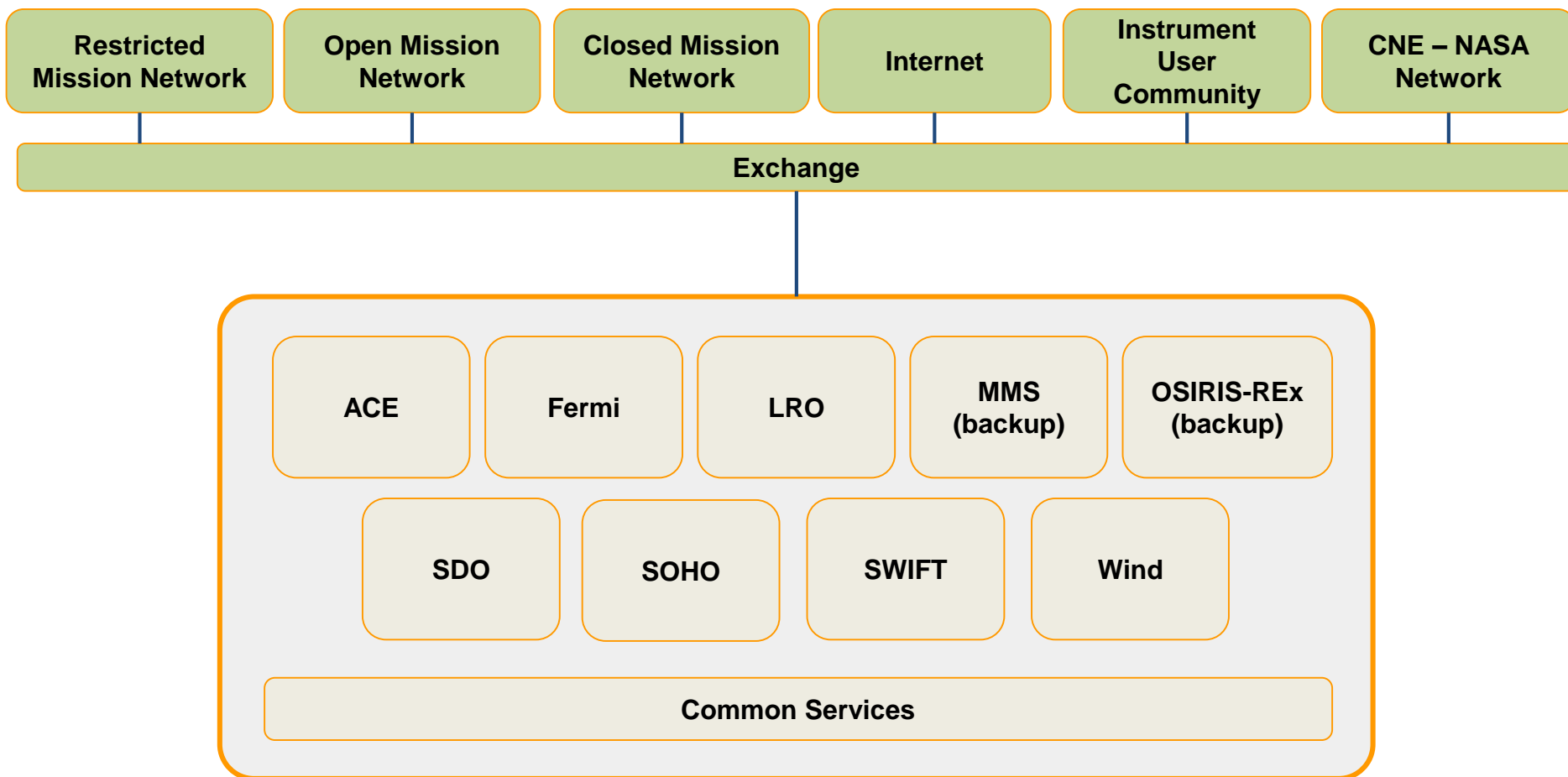
What is the vMMOC?



- **Multiple-missions Operated from one center**
- **Local virtualized infrastructure**
- **Access to a secure public cloud computing infrastructure**
- **Situational Awareness Dashboard (a SaaS)**
- **Telemetry as a Service (TaaS)**
 - **Soon to be *Telemetry, and Tracking as a Service* (TTaaS)**
- **Navigation as a Service (NaaS)**



vMMOC's High Level Infrastructure





What is the vMMOC?



- **Shared:**
 - Infrastructure
 - Product formats
 - Networking interfaces
 - Workflows & Procedures
 - Security implementations
 - Hardware and software
 - Core staff
 - Lessons-learned
 - Culture

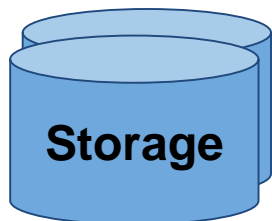
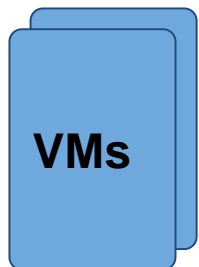
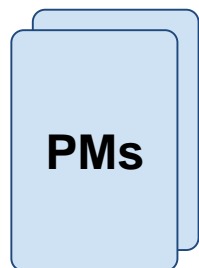


What is the vMMOC?



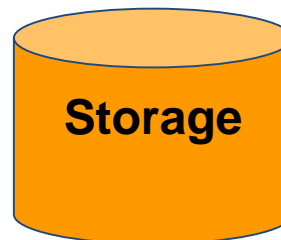
Private virtualized infrastructure

GSFC - SSMO



Public Cloud Computing (secured)

AWS GovCloud



Data Producers & Consumers





Situational Awareness Dashboard



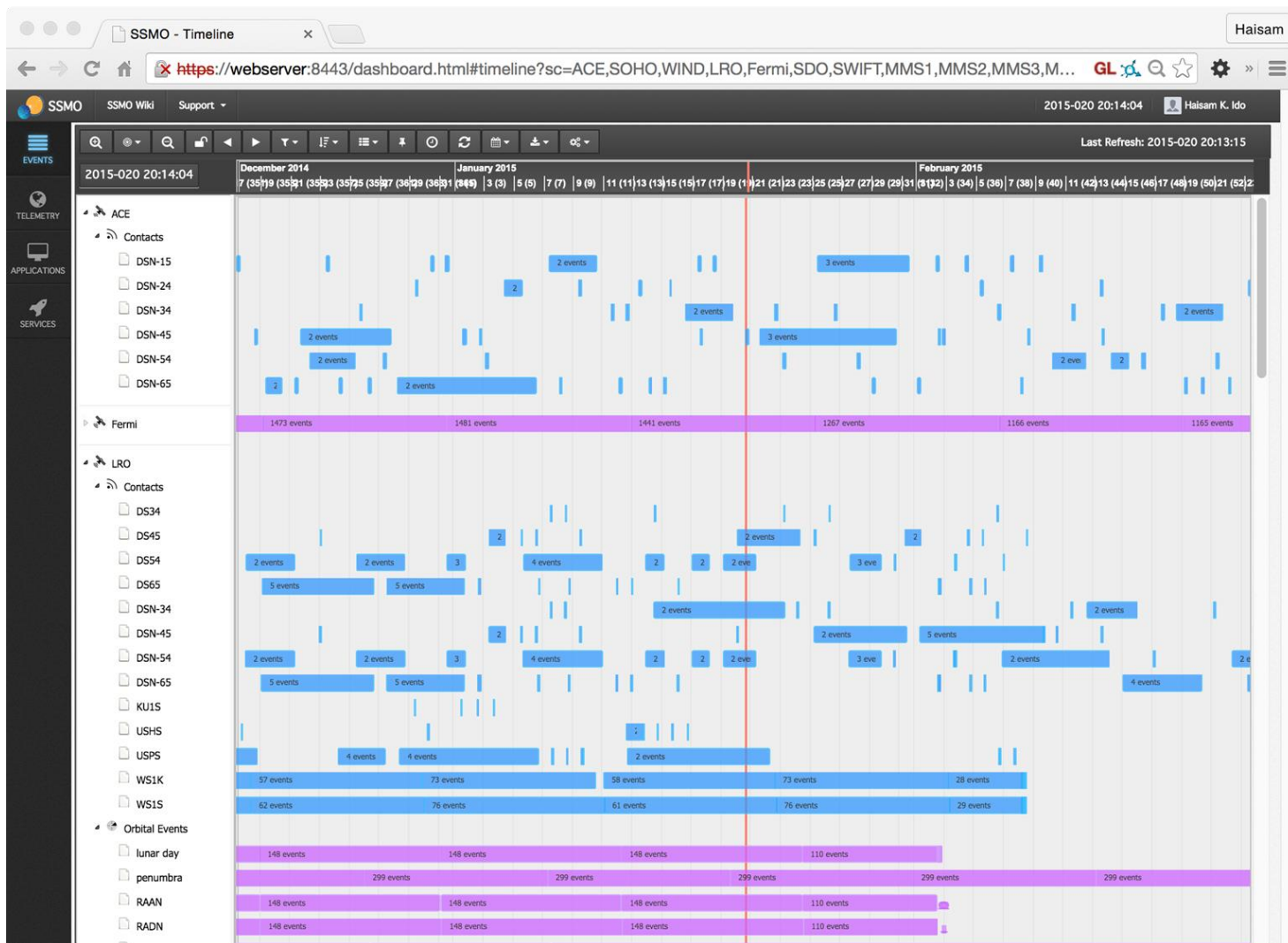
Break the barrier to data access

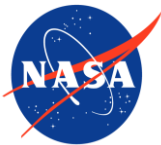


- **Provide local and remote users an integrated, situational awareness dashboard of major spacecraft and ground events**
 - Secure
 - Tailorable, self-service capability to access all spacecraft timelines
 - Liberate the data
 - Empower each engineer to tailor requests for any SSMO spacecraft
- **A web service based on NIST's Software as a Service (SaaS) model**

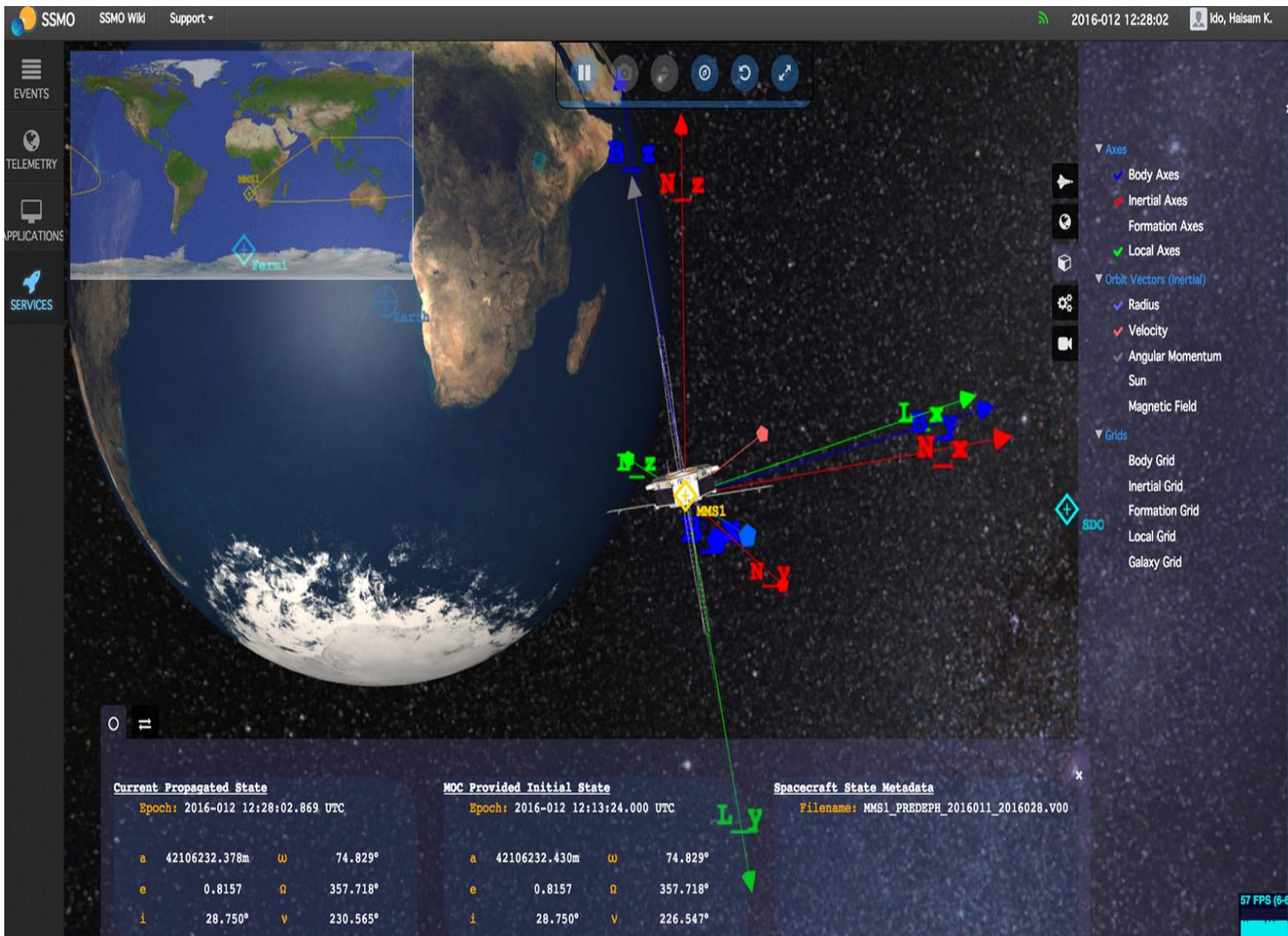


A timeline view of ACE, Fermi and LRO



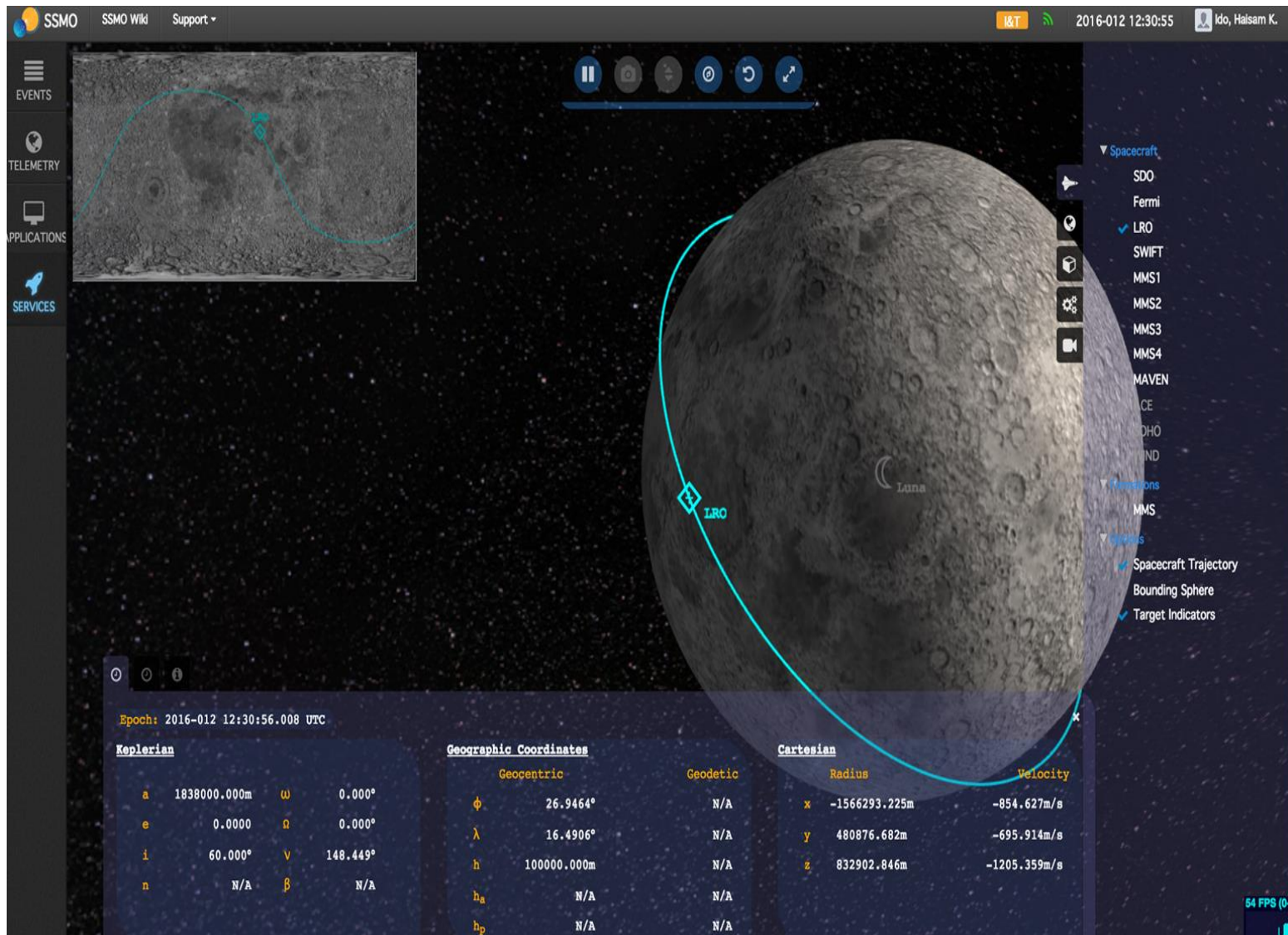


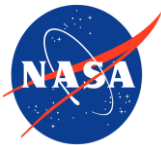
A view of a closeup of MMS1





A view of LRO





Execute General Mission Analysis Tool (GMAT) in the cloud

SSMO - VFS Editor

https://webserver:8443/dashboard.html#vfs-editor

SSMO SSMO Wiki Support

2015-020 20:18:32 Haisam K. Ido

My Drive

GMAT

output

GmatLog.txt

targeter_DefaultDC.data

samples

Ex_Attitude_Inertial.script

Ex_Attitude_ModifiedRodriguez

Ex_Attitude_NadirPointing.script

Ex_Attitude_Spinner.script

Ex_Attitude_VNB.script

Ex_Basic3DModel.script

Ex_Cart2KepMathTest.script

Ex_ConstellationScript.script

Ex_ControlFlow.script

Ex_DoubleLunarSwingby.script

Ex_FileInterface.script

Ex_FiniteBurn.script

Ex_ForceModels.script

Ex_GEOTransfer.script

Ex_GivenEpochGoToTheMoon.sc

Ex_GMATFunction.script

Ex_HohmannTransfer.script

Ex_Integrators.script

Ex_L2Design.script

Ex_LCROSSTrajectory.script

Ex_LEOSStationKeeping.script

Ex_LibrationPointStationKeepi

Ex_LunarOrbitStationKeeping.sc

Ex_LunarTransfer.script

Ex_MarsBPlane.script

Ex_MarsOrbit.script

Ex_MMSSingleLunarSwingby.scri

Ex_SafetyEllipse.script

Ex_HohmannTransfer.script

```
1 % Script Mission - Hohmann Transfer Example
2 % This script demonstrates how to target a Hohmann Transfer
3
4
5
6 %----- Spacecraft
7
8
9
10 Create Spacecraft DefaultSC;
11 GMAT DefaultSC.DateFormat = 'TAIModJulian';
12 GMAT DefaultSC.Epoch = '21545';
13 GMAT DefaultSC.CoordinateSystem = EarthMJ2000Eq;
14 GMAT DefaultSC.DisplayStateType = Cartesian;
15 GMAT DefaultSC.R = 7100;
16 GMAT DefaultSC.V = 0;
17 GMAT DefaultSC.A = 1300;
18 GMAT DefaultSC.VX = 0;
19 GMAT DefaultSC.VY = 7.35;
20 GMAT DefaultSC.VZ = 1;
21 GMAT DefaultSC.DryMass = 850;
22 GMAT DefaultSC.Cd = 2.2;
23 GMAT DefaultSC.Cr = 1.4;
24 GMAT DefaultSC.DragArea = 15;
25 GMAT DefaultSC.SRPArea = 1;
26 GMAT DefaultSC.HALFId = -123456789;
27 GMAT DefaultSC.HALFIdReferenceFrame = -123456789;
28 GMAT DefaultSC.Id = 'SatId';
29 GMAT DefaultSC.Attitude = CoordinateSystemFixed;
30 GMAT DefaultSC.ModelFile = '../data/vehicle/models/aura.3ds';
31 GMAT DefaultSC.ModelOffsetX = 0;
32 GMAT DefaultSC.ModelOffsetY = 0;
33 GMAT DefaultSC.ModelOffsetZ = 0;
34 GMAT DefaultSC.ModelRotationX = 0;
35 GMAT DefaultSC.ModelRotationY = 0;
36 GMAT DefaultSC.ModelRotationZ = 0;
37 GMAT DefaultSC.ModelScale = 3;
38 GMAT DefaultSC.AttitudeDisplayStateType = 'Quaternion';
39 GMAT DefaultSC.AttitudeRateDisplayStateType = 'AngularVelocity';
40 GMAT DefaultSC.AttitudeCoordinateSystem = 'EarthMJ2000Eq';
41
42 %----- ForceModels and Propagators
43 %-----
44
45 Create ForceModel DefaultProp_ForceModel;
46 GMAT DefaultProp_ForceModel.CentralBody = Earth;
47 GMAT DefaultProp_ForceModel.PointMasses = {Earth};
48 GMAT DefaultProp_ForceModel.Drag = None;
49 GMAT DefaultProp_ForceModel.SRP = Off;
50 GMAT DefaultProp_ForceModel.RelativeViscousCorrection = Off;
51 GMAT DefaultProp_ForceModel.ErrorControl = RSSStep;
52
53 %----- Propagators
54 %-----
55
56
```

Output

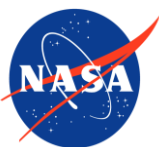
*****GMATCloud Execution Started

***** GMAT Console Application

General Mission Analysis Tool
Console Based Version
Build Date: May 21 2014 11:27:50

Noderator is creating core engine...

Execution of "Ex_HohmannTransfer.script" has completed. (click to hide)



Telemetry as a Service (TaaS)



Break the barrier to data access



- **Provide local & remote users access to *telemetry & tracking***
 - Secure
 - Tailorable, self-service capability to access all SSMO spacecraft telemetry & tracking:
 - Liberate the data
 - Empower each engineer to tailor requests for any SSMO spacecraft
 - Each engineer can perform analysis without interfering with operations workflows
- **A web service based on NIST's Software as a Service (SaaS) model**



A view of the portal

≡

TaaS

2017-019-00:00:00

2017-022-00:00:00

UTC ▾

6

WORKSPACE

SEARCH

GRAPH

Selected Mnemonics

| | SPACECRAFT | PACKET | MNEMONIC | MNEMONIC DESCRIPTION | | | |
|-------------------------------------|----------------------|----------------------|----------------------|---|--|---------|--|
| <input type="checkbox"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | | CVT ▾ | |
| <input checked="" type="checkbox"/> | Fermi | 11 | SAC_MODE | GNC_TLM_MODE Telemetry (SIANCILLARY GNC_MODE). Current spacecraft ACS mode | | CVT ▾ | |
| <input checked="" type="checkbox"/> | LRO | 203 | ACRW1SPD | Reaction Wheel 1 Wheel Speed | | CVT ▾ | |
| <input checked="" type="checkbox"/> | MMS1 | 126 | PSE_BATV | 'PSE_PMC0_BATT_V' BATTERY MODULE ANALOG BATTERY VOLTAGE ; P306,8 pwr rtn to chs(+) 23 chs to pwr rtn(-) | | CVT ▾ | |
| <input checked="" type="checkbox"/> | SDO | 138 | ACS_P_DIAG[1] | Kalman Filter covariance diagonal element 1,2,3,4,5,6. | | CVT ▾ | |
| <input checked="" type="checkbox"/> | Swift | 16 | SAC_MODE | ACS_TLM_MODE Telemetry. Current spacecraft ACS mode | | CVT ▾ | |
| <input checked="" type="checkbox"/> | Swift | 16 | SAC_MODE | ACS_TLM_MODE Telemetry. Current spacecraft ACS mode | | UNCVT ▾ | |

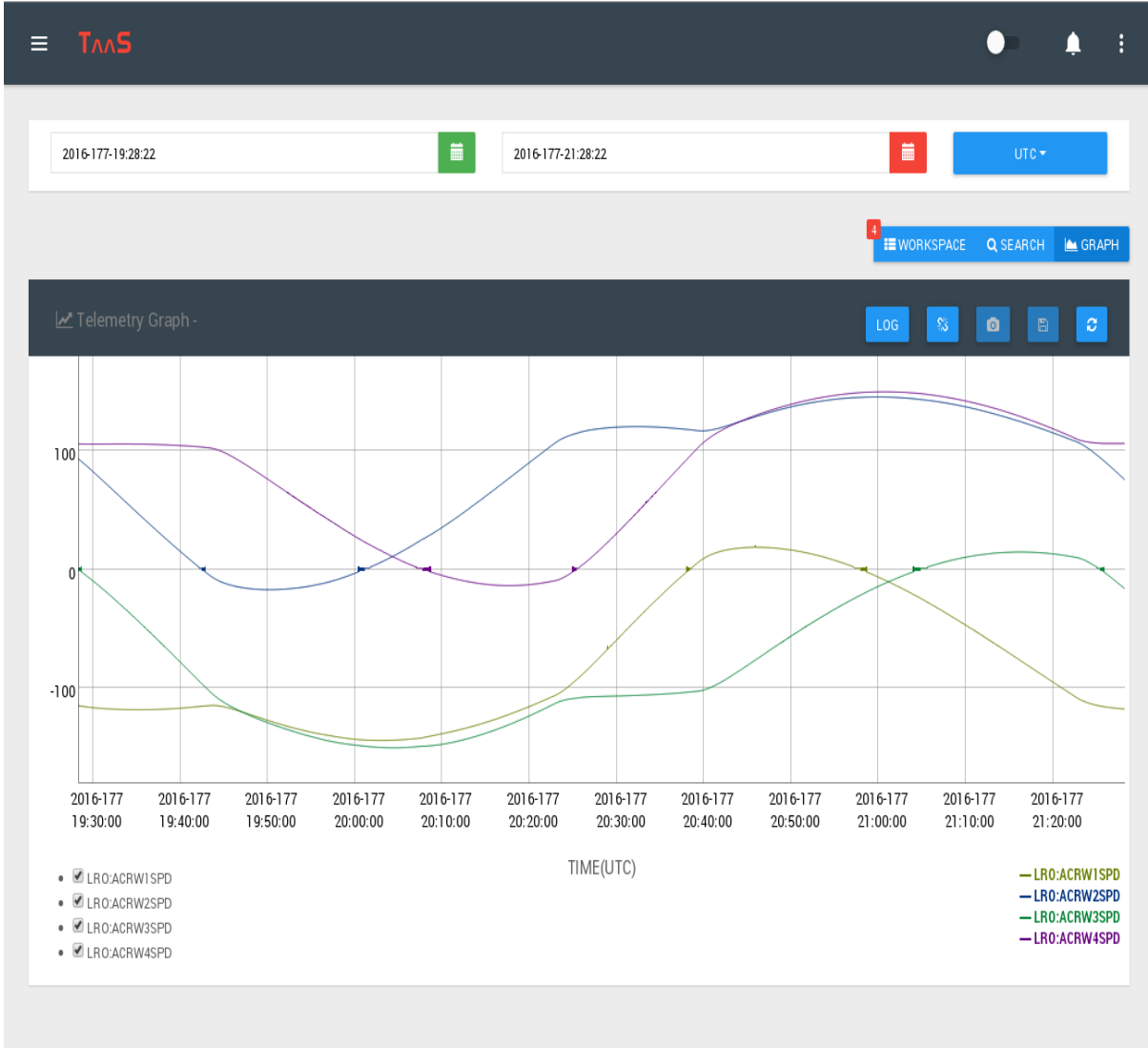
10

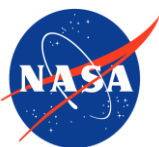
25

50

100

A view of a plot of wheel speeds





Navigation as a Service (NaaS)



Break the barrier to data access



Navigate the Spacecraft in Support of Mission Operations

Navigation Services

- Maneuver planning
- Maneuver execution
- Maneuver reconstruction
- Orbit estimation & control
- Attitude estimation & control

Scheduling & Planning in Support of Navigation

- Maneuvers
- Network Availability
- Antenna Availability
- AOS/LOS
- Shadows
- Interference
- Tracking



“Looking Beyond the Horizon”



How would one simulate hundreds of spacecraft?



- **With the coming age of OneWeb, and other massive spacecraft operations proposals, how does one:**
 - Design, Model and Simulate Ground and Space Segments ?
- **Leverage Cloud Computing & Create Service Models, such as:**
 - Spacecraft as a Service (SCaaS)
 - Flight Software as a Service (FSWaaS)
 - Ground Segment as a Service (GSaaS)
 - Auto Provision, Orchestrate & Terminate services at will



Thank you.

Any Questions?